Spectroscopic analysis of Geminid meteors

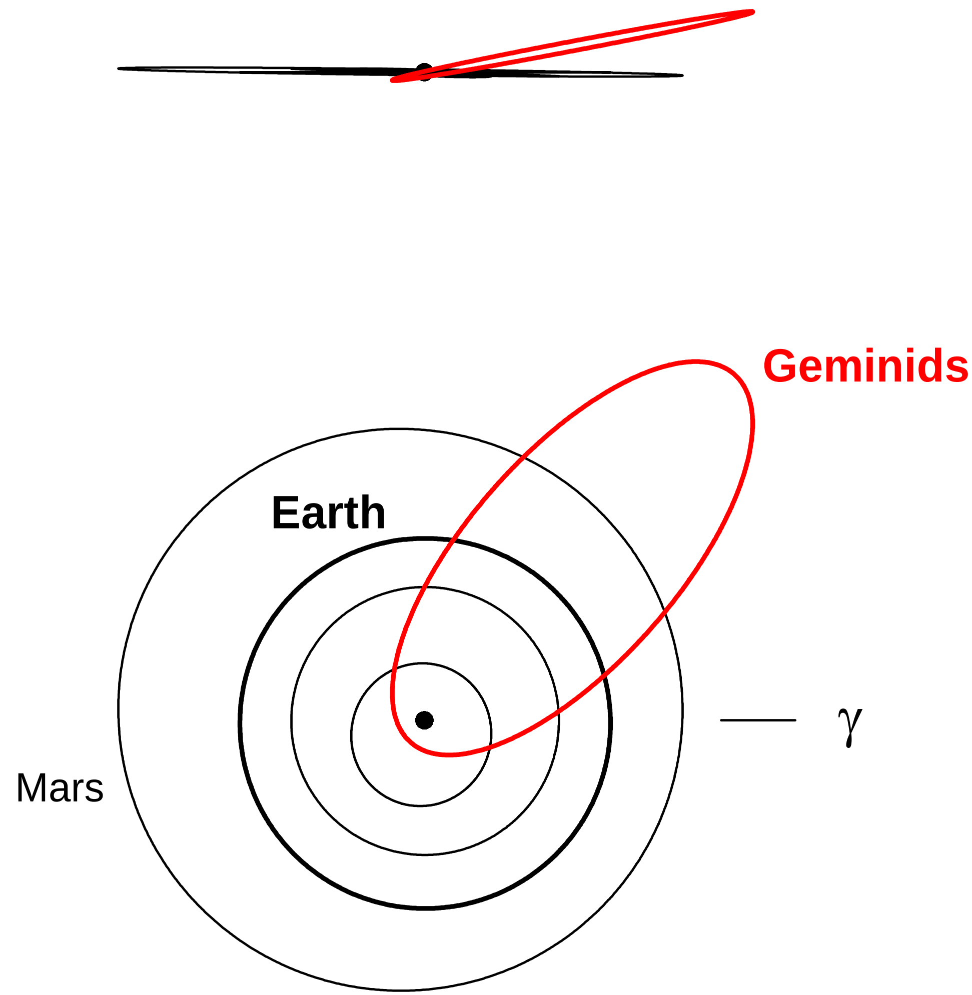
Jiri Borovicka

Astronomical Institute, Academy of Sciences, Ondrejov, Czech Republic

borovic@asu.cas.cz

Peculiarities of Geminid meteor shower

- short period (1.5 yr)
- small perihelion distance (0.14 AU)



Parent body: 3200 Phaethon

- Discovered in 1983 by the IRAS satellite (Geminids are known since the 19^{th} century)
- Diameter 5 km
- Spectral type: F
- Only 10 asteroids have smaller perihelion distance

(JPL Small-Body Database)

Geminid interplanetary complex

- Geminids, Daytime Sextantids, 3200 Phaethon, and asteroid 2005 UD have similar orbits and probably have a common origin

(Ohtsuka et al. 2006)

Peculiarities of Geminid meteoroids

- Atmospheric behavior of Geminids differs from that of typical cometary showers
  - beginning heights, end heights, ablation coefficients, light curves
- Geminids are less fragile and more compact than cometary meteoroids – their properties are closer to asteroidal meteoroids
  - bulk density ~ 3 g/cm^3

(Spurny 1993; Babadzhanov 2002; Koten et al. 2004 ….)

QUESTIONS

- Is Phaethon a regular asteroid or dormant (or extinct) comet?

- How was the Geminid stream formed?

Recent work

- No cometary activity of Phaethon was found, mass loss rate < 0.01 kg/s

  (Hsieh & Jewitt 2005)
- The stream is several thousands years old, the stream was possibly formed during one orbital revolution (Ryabova 2006)
- Meteoroids approaching Sun ($q < 0.2$ AU) loose volatiles (Na) and are compacted

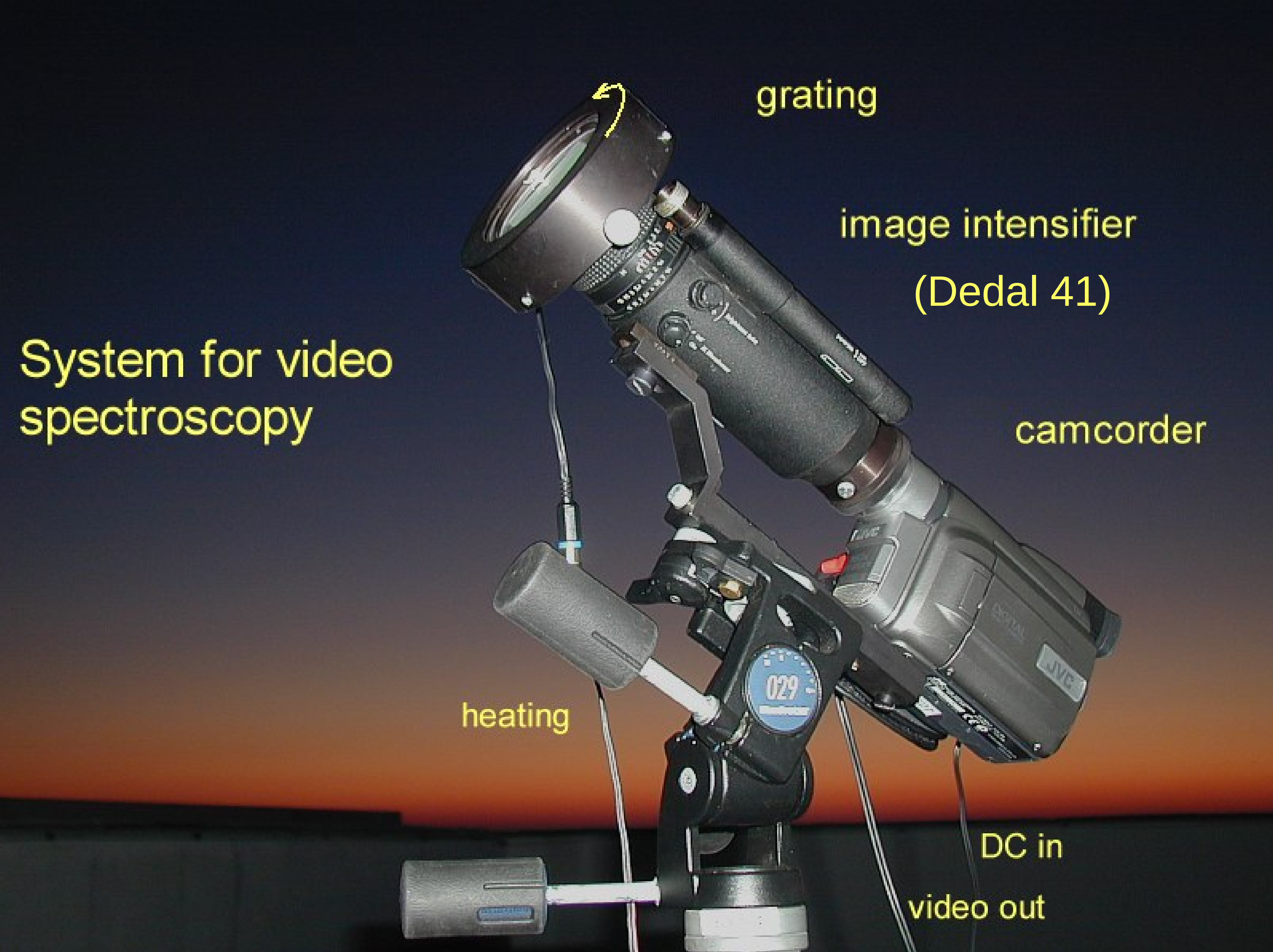
  (Borovicka et al. 2005)

This work

- Analysis of 89 video spectra and 2 photographic spectra of Geminid meteors, magnitudes +2 and brighter
- Meteoroid mass range: $10^{-6} – 3\times10^{-4}$ kg (∅ 1 – 6 mm) and several grams (∅ ~ 1 cm)
- Study of Geminid chemical composition, in particular the ratios

Na/Mg

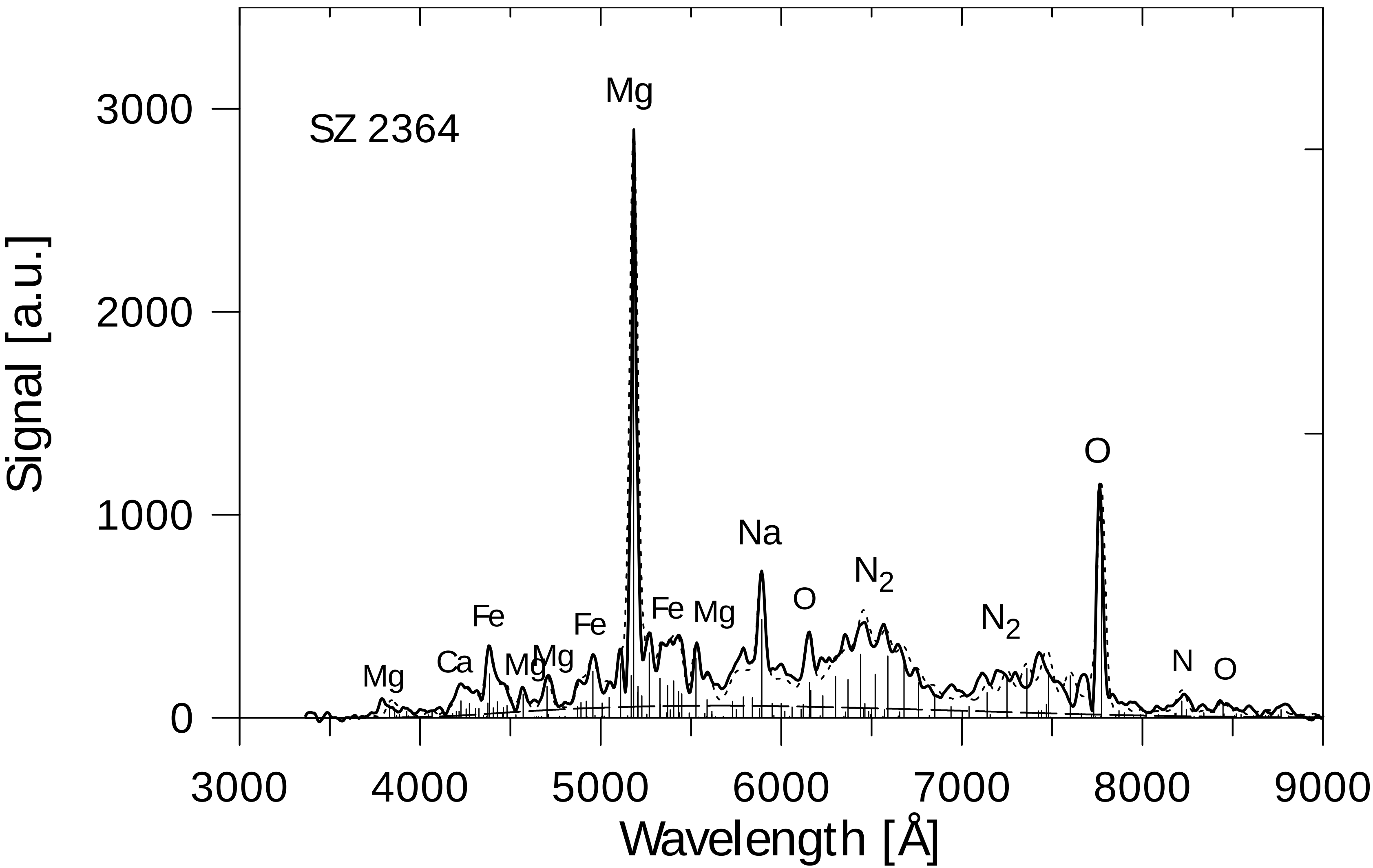
Fe/Mg


System for video spectroscopy
grating
image intensifier
(Dedal 41)
camcorder
heating
DC in
video out

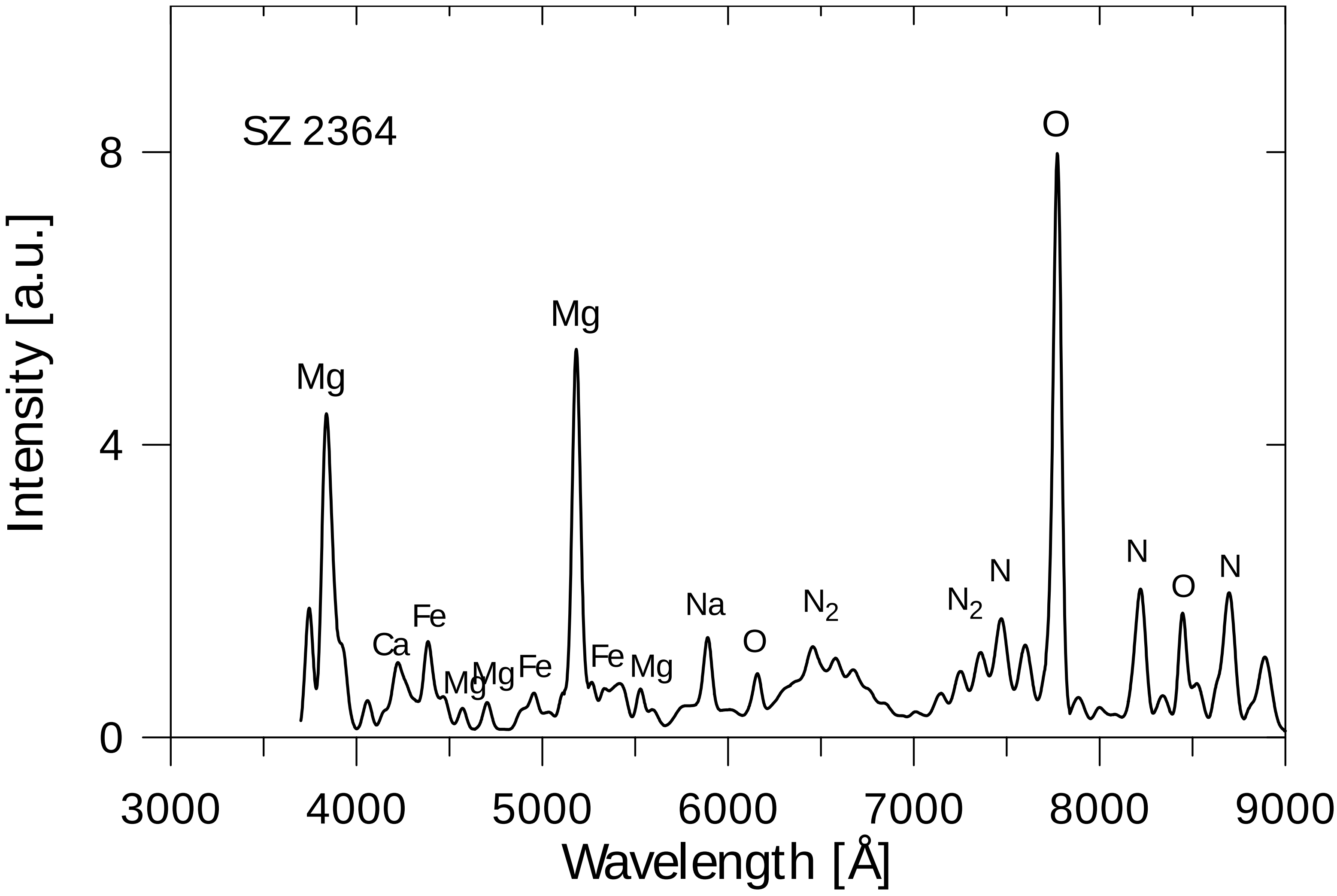
Video Spectrum

Single video frame

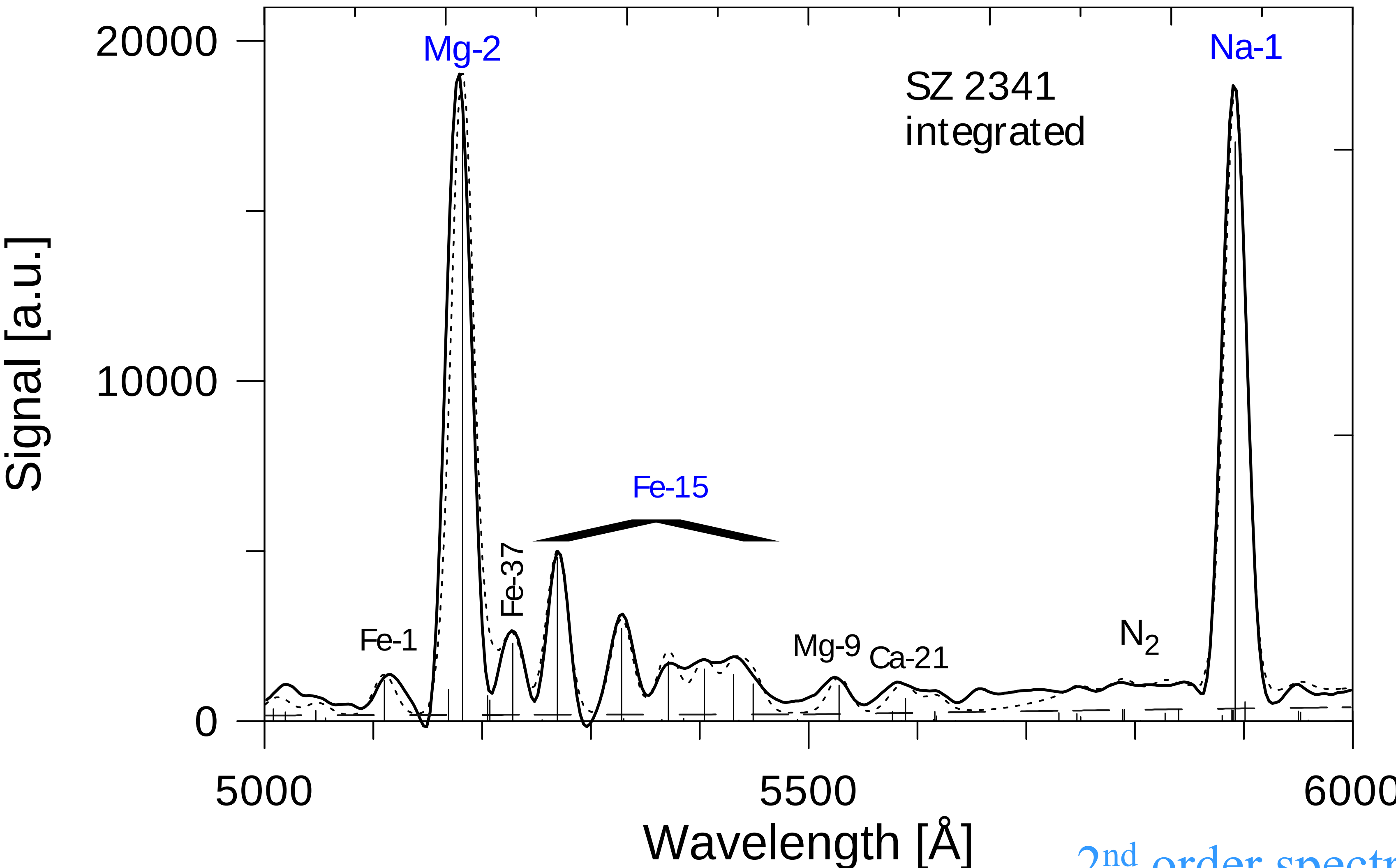
Extracted spectrum – not calibrated



Extracted spectrum – calibrated



The studied Mg, Na, and Fe lines



2nd order spectrum

Solar system abundances

- Derived from the analysis of carbonaceous meteorites (CI) and solar photosphere
- Believed to reflect the original composition of the solar nebula

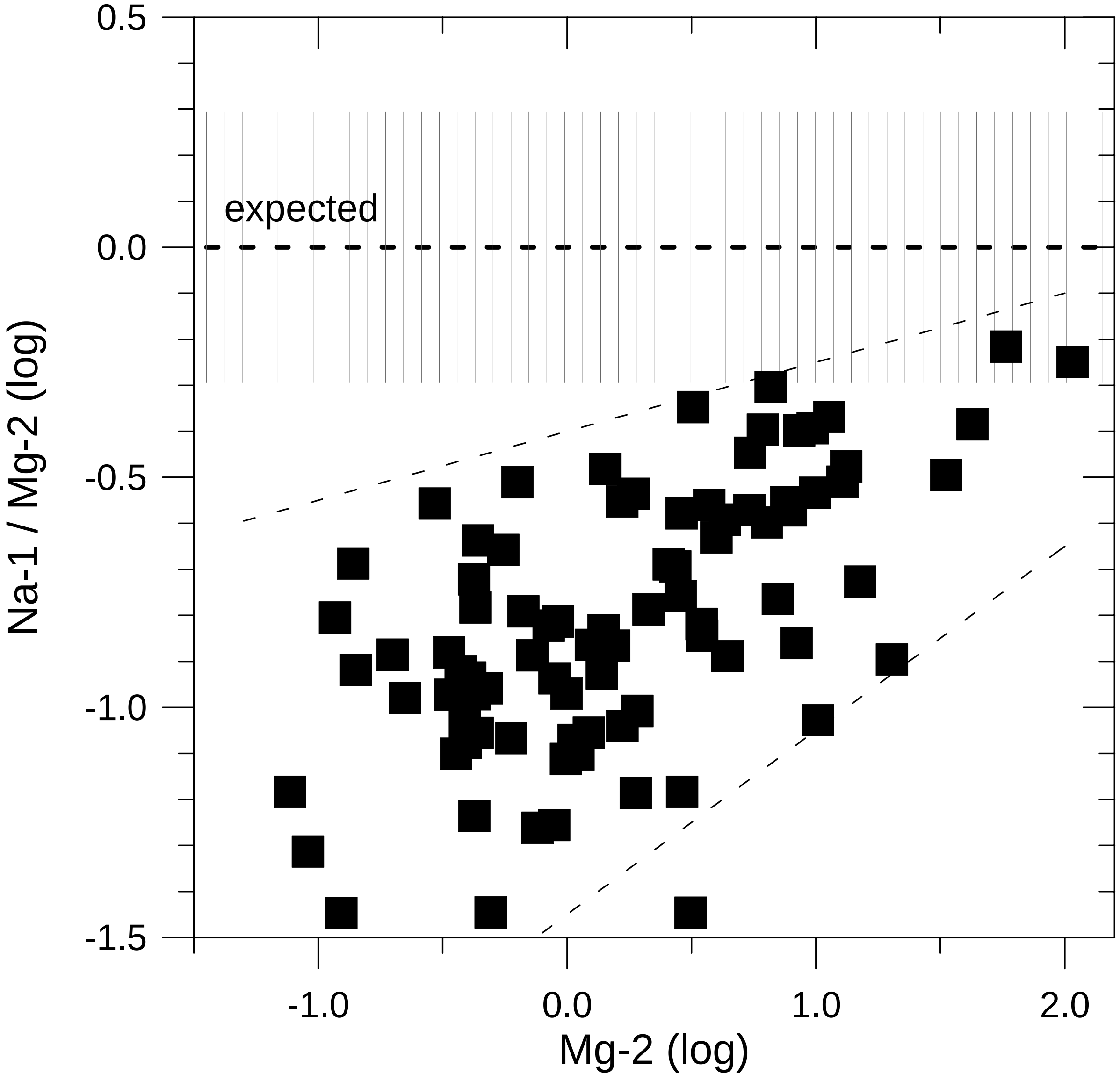
$$Fe/Mg = 0.82$$

$$Na/Mg = 0.056$$

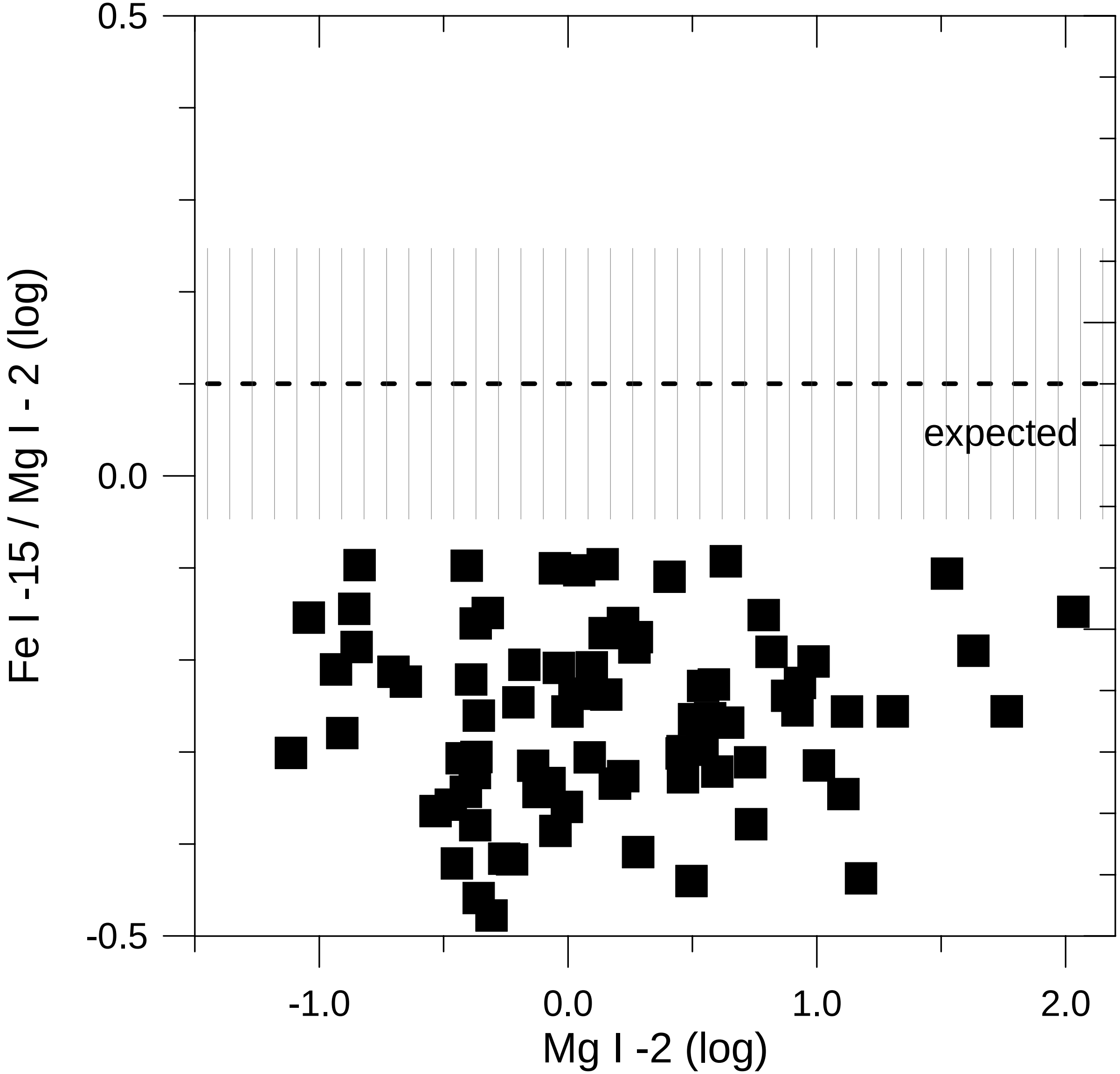
Theoretical line intensities

- Mg, Na, Fe lines are produced by hot meteoroid vapors
- We assume thermal equilibrium. Line intensities depend on vapor temperature, density, mass, and on vapor composition
- Temperatures 4000 – 4500 K are most appropriate for Geminids

Observed Na/Mg line ratios

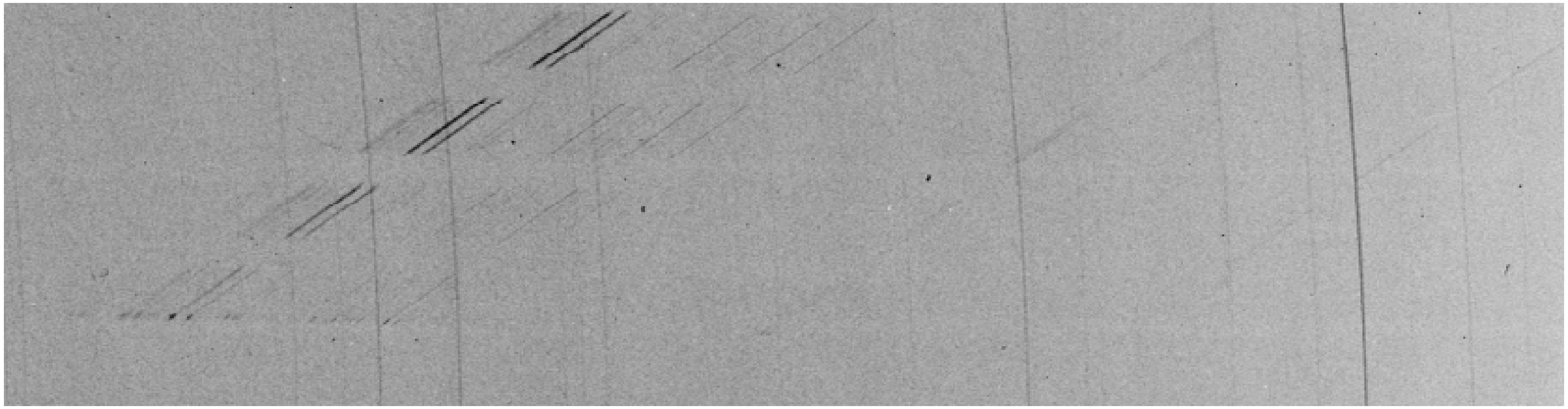


Observed Fe/Mg line ratios

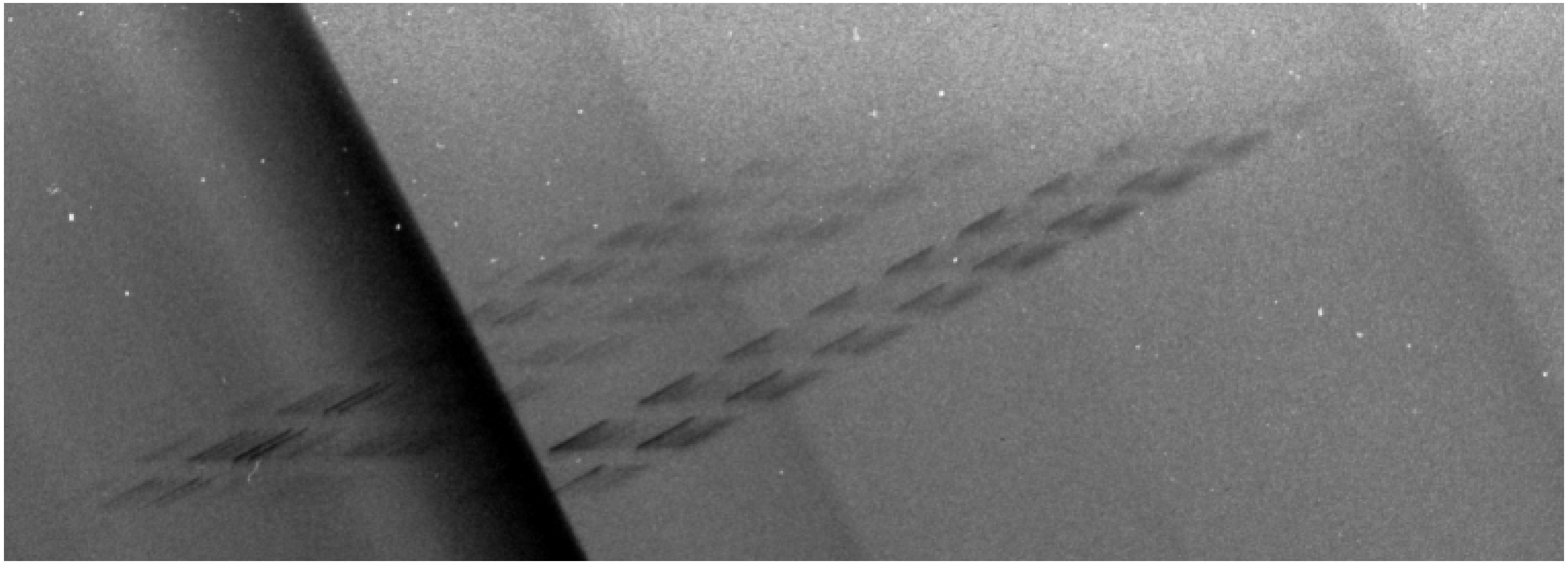


Battery of six photographic grating cameras with rotating shutter in Ondřejov

Photographic spectra

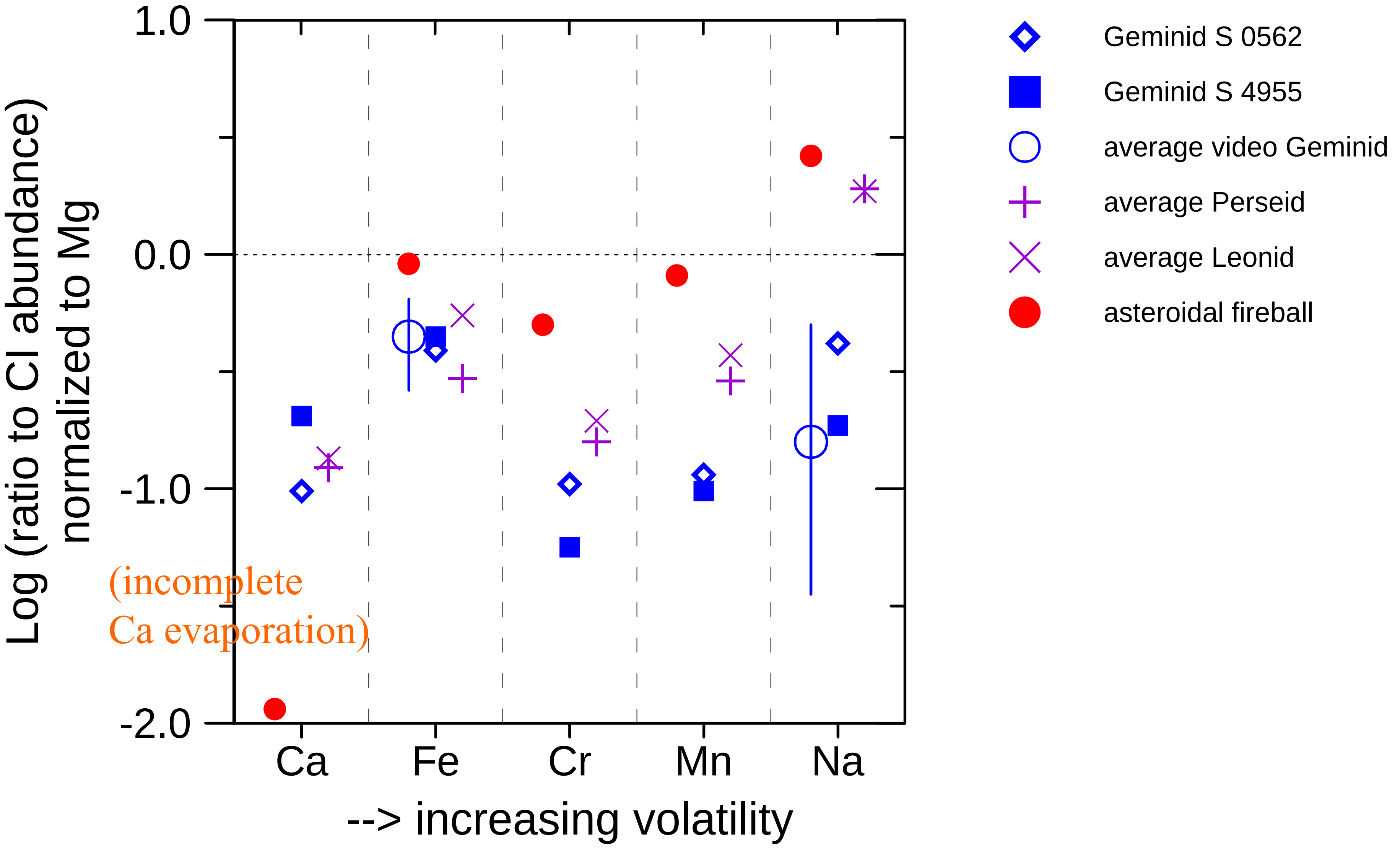


S 0562
grating



S 4955
prism

Comparison of abundances



SUMMARY AND DISCUSSION

- Fe/Mg ratio
- Na/Mg ratio
- Na variations

Fe/Mg ratio

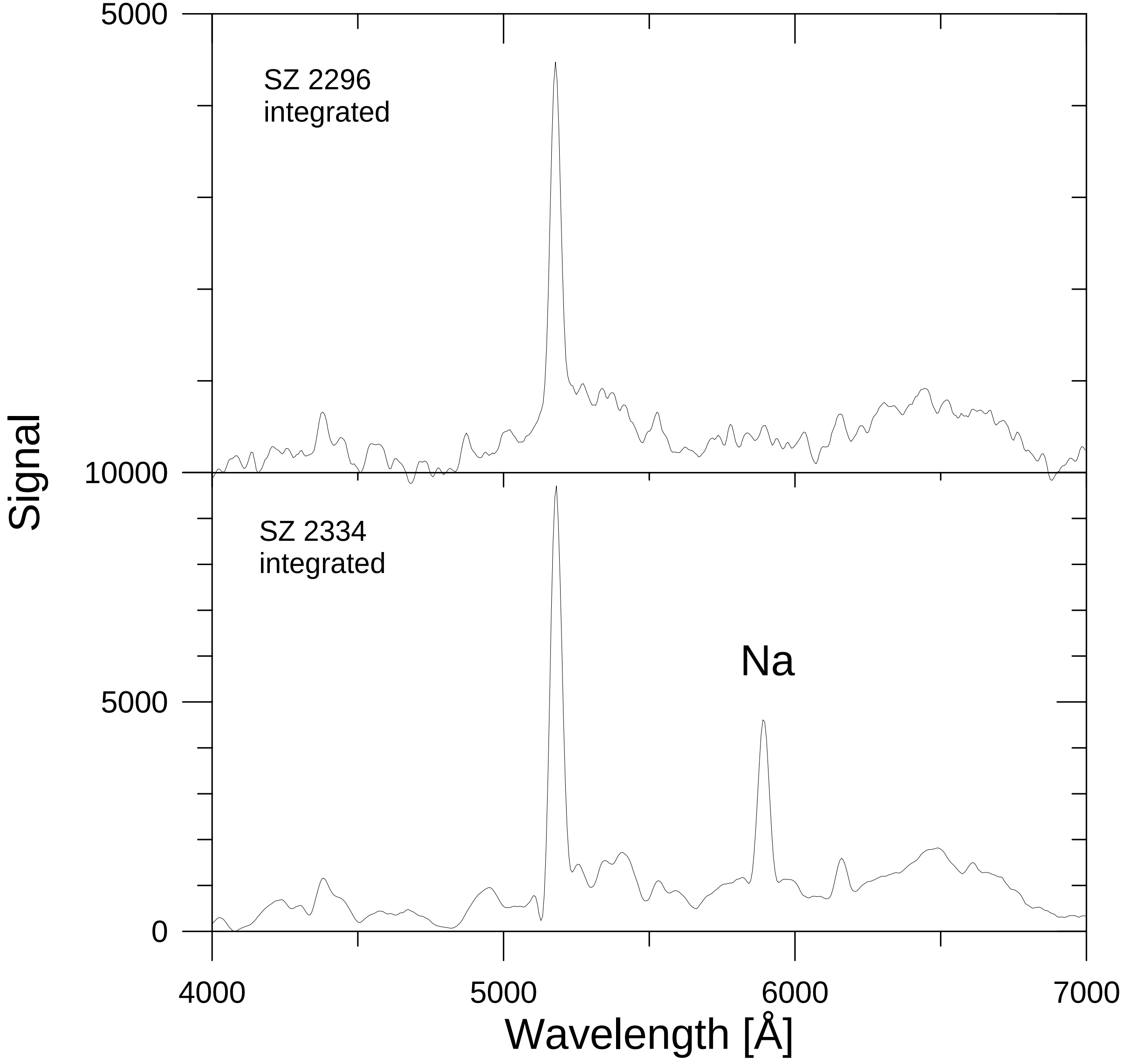
- Lower (2×) than chondritic Fe/Mg is indicative of cometary origin of Geminids
  - ratio is similar to Perseids and Leonids
  - cometary dust is Mg-rich

(Jessberger et al. 1988, Hanner & Bradley 2004)

Na/Mg ratio

- The Na/Mg ratio shows large variations from meteor to meteor but is always lower than chondritic (2× to >10×)
- Loss of Na due to heating in the vicinity to the Sun (0.14 AU)

Na variations are real

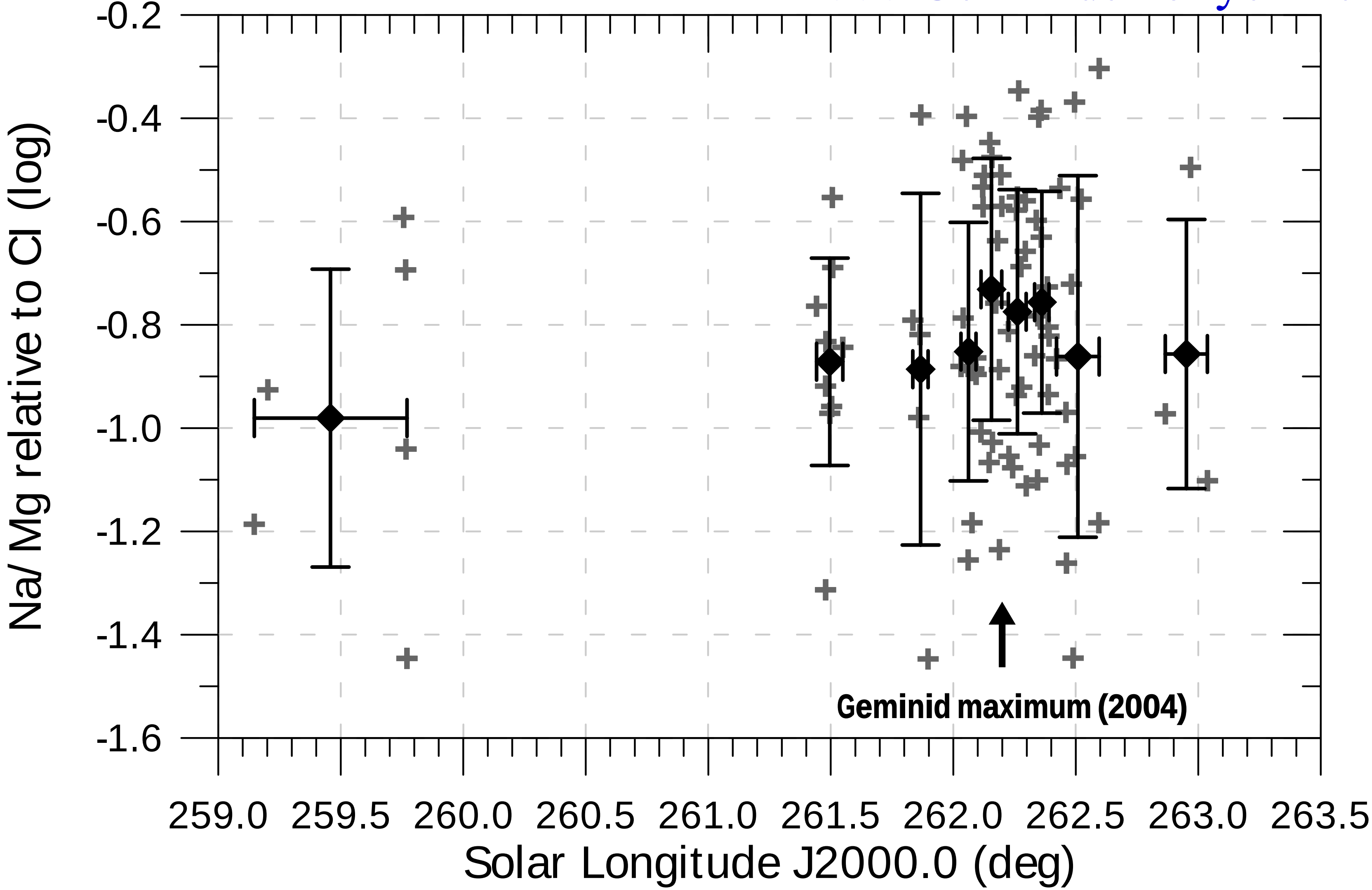


Possible minor dependency of Na/Mg ratio on mass

- May be an effect of ablation in the atmosphere
- May be real abundance effect (smaller meteoroids are loosing Na more quickly)

Na/Mg across the stream

2006 Geminids not yet included



Proposed explanations of Na variations

1. Different ages of meteoroids (age = time since the release from Phaethon) PREFFERED
2. Release from different depth inside Phaethon (surface was more influenced by solar radiation)
3. Internal Phaethon inhomogeneity on mm scales

CONCLUSIONS

- Phaethon is an inactive cometary nucleus
- The Geminid stream was likely produced over a prolonged period of time